The Development of the Prototype of Bamboo Shading Device

N. Tuaycharoen, W. Konisranukul

***Abstract*—**The main aim of this research was to investigate a prototype bamboo shading device. There were two objectives to this study: first, to investigate the effects of non-chemical treatments on bamboo shading devices damaged by powder-post beetles and fungi, and second to develop a prototype bamboo shading device. This study of the effects of non-chemical treatments on bamboo shading devices damage by powder-post beetles in the laboratory showed that, among seven treatments tested, wood vinegar treatment can protect powder-post beetles better than the original method by up to 92.91%. It was also found that wood vinegar treatment shows the best performance in fungi protection and works better than the original method by up to 40%. A second experiment was carried out by constructing four bamboo shading devices and installing them on a building for 28 days. All aspects of shading device were investigated in terms of their beauty, durability, and ease of construction and assembly. The final prototype was developed from the lessons learned from the test results. In conclusion, this study showed the effectiveness of some natural preservatives against insect and fungi damage, and it also illustrated the characteristics of a prototype bamboo shading device that can be constructed by rural workers within one week.

***Keywords*—**Bamboo, shading device, energy conservation, alternative materials.

I. Introduction

BAMBOO is perhaps the fastest growing plant on the planet, and is a plant generally found in most Asian countries [1]. Because bamboo ingests CO_2 from the atmosphere and through the process of photosynthesis turns it into sugar, bamboo offers the quickest way to remove vast amounts of carbon dioxide from the atmosphere as long as it lives. A bamboo building can remove over 15 tons of carbon dioxide, for every 100 square meters of covered floor area, from the atmosphere [1]. In addition, previous documentary evidence shows that a bamboo shading device displays a similar performance to aluminium in protecting against the sun, but it uses much lower embodied energy in its production processes [2], [3].

Most research concerning treatments used to enhance the durability of bamboo has concentrated on chemical preservative treatment methods [4]-[6]. They included for example: Copper-chrome-arsenic (CCA), Copper-chrome-boron (CCB), Ammoniacal-copper-arsenite composition, and Acid-copper-chrome composition. Apart from the original method of soaking and drying bamboo, there have been very few studies about environment-friendly chemicals used to prevent damage to bamboo by mould and fungi [7], and neither has work been carried out on non-chemical preservative treatment methods to increase the durability of bamboo. Furthermore, in terms of designs of bamboo to be used as building elements, most studies were completed on the assumption that bamboo development comprised composite panels. There have been several attempts to explore the possibility of producing panel products, which include: particleboards, oriented stand-boards, plywood and laminated composite panels made of bamboo at the commercial level [8]-[14]. Some studies concentrated on building main structures [15]-[17], and furniture [18].

In 2010, [2] illustrated that the best characteristic of a bamboo shading device is box- shaped, with 5cm wide slats and an inclination of 30^{o} from the horizontal. The results of this study show that using bamboo as an alternative material for shading devices can induce much less energy consumption than other present materials. Bamboo is however destroyed by insects, and is highly sensitive to moisture [19]. Therefore, in order to create a practical bamboo shading device, extensive research was required to investigate its strength and durability. Additionally, to produce a prototype bamboo shading device as an industrial product, it is essential to consider detailing the design with regards to its beauty, durability, and ease of construction and assembly.

The main aim of this research was thus to develop a prototype bamboo shading device. There were two objectives of this study: The first objective was to explore the effects of non-chemical treatments on a bamboo shading device damaged by powder-post beetles and fungi. The second aim of this study was to develop a prototype bamboo shading device in terms of detailing its design with regards to its beauty, durability, and ease of construction and assembly. It is hoped that the prototype bamboo shading device proposed in this study may be used as an industrial product in Thailand.

II. Experiment I: Non-Chemical Preservatives and Power-Post Beetle and Fungi Decaying

A. The Objectives of This Study

The aim of the experiment was to explore the effects of non-chemical treatments on bamboo shading devices damaged by powder-post beetles and fungi.

B. Research Methodology

3-year old *Pai Tong* bamboo was used in this experiment. Pieces of bamboo 5cm wide x 20cm long with 3mm thickness

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were tested using non-chemical treatments. Seven non-chemical preservatives were employed, which consisted of: 1) soaking in water and heating (original method), 2) soaking in lemon grass solution, 3) immerging in turmeric solution, 4) immerging in celery solution, 5) immerging in wood vinegar solution, 6) immerging in tobacco solution, and 7) soaking in neem leaf solution. The bamboo pieces were immerged in each solution for one month. After that there were two further tests. The first test was a laboratory test which was completed at the Department of Plant Pathology, Faculty of Agriculture, Kasetsart University.

The second test was a field study at the Faculty of Architecture, Naresuan University. The degree of damage by powder-post beetles was measured by counting the numbers of hollow damage. The degree of damage by fungi was measured by counting the percentage of damage. The number '0' means no damage; '1' means 1-25% damage; '2' is 26-50% damage, and '3' is 51-100% damage. The experimental design was 'A Repeated Measure Balance Latin Square', and a 'Repeated Measure One-way ANOVA' was employed for statistical analysis.

C. Results

TABLE I
THE EFFECT OF NON-CHEMICAL TREATMENT OF PRESERVATIVES FOR POWER-POST BEETLE DAMAGE (1 AND 2 WEEK PERIOD) IN LABORATORY

Piece of Bamboo	Water and heating		Lemon grass		Turmeric		Celery	
Week	1	2	1	2	1	2	1	2
1	75	70	24	22	17	16	12	10
2	25	20	7	5	15	15	0	1
3	46	40	14	12	9	10	5	6
4	57	51	45	43	45	42	17	18
5	47	43	2	3	3	2	17	18
Average	47.40		17.70		17.40		10.40	

Piece of Bamboo	Wood vinegar		Tobacco		Neem leaf	
Week	1	2	1	2	1	2
1	5	6	11	10	12	13
2	0	1	1	2	6	7
3	2	3	8	7	8	9
4	7	8	20	19	30	28
5	0	1	12	13	1	2
Average	3.30		10.30		11.60	

Table I illustrates the effects of non-chemical treatment of preservatives for power-post beetle damage (1 and 2 week periods) in laboratory testing. It was found that the wood vinegar solution was the best protection against power-post beetle damage (mean = 3.30). The second was a tobacco solution (mean = 10.30), and the third was a celery solution (mean = 10.40). When comparing a wood vinegar solution to the original method of water soaking and heating, it was found that immerging bamboo in a wood vinegar solution could reduce damage by power-post beetles by 93.04%. One-way ANOVA showed a significant difference between damage by power-post beetles from the 7 treatments and that the differences were highly significant ($p< 0.01$).

TABLE II
THE EFFECT OF NON-CHEMICAL TREATMENT OF PRESERVATIVES FOR POWER-POST BEETLE DAMAGE (1 AND 3 MONTH PERIOD) IN FIELD STUDY

Piece of Bamboo	Water and heating		Lemon grass		Turmeric		Celery	
Month	1	3	1	3	1	3	1	3
1	45	45	28	34	10	10	9	10
2	25	20	4	5	10	12	0	1
3	36	36	10	14	10	10	4	6
4	35	37	25	30	34	35	16	20
5	20	27	7	3	2	7	16	19
Average	31.60		16.00		14.00		10.10	

Piece of Bamboo	Wood vinegar		Tobacco		Neem leaf	
Month	1	3	1	3	1	3
1	6	2	11	10	11	12
2	0	1	2	2	9	9
3	1	2	8	10	9	12
4	4	7	22	22	29	32
5	0	0	11	11	4	5
Average	2.30		10.90		13.20	

Table II illustrates the effects of non-chemical treatment of preservatives for power-post beetle damage (1 and 3 month periods) in field study tests. It was found that a wood vinegar solution was the best protection against power-post beetle damage (mean = 2.30). The second was a celery solution (mean = 10.10), and the third was a tobacco solution (mean = 10.90). Comparing a wood vinegar solution to the method of water soaking and heating, and then immerging bamboo into a wood vinegar solution, could reduce damage by power-post beetles by 92.72%. One-way ANOVA showed a highly significant difference between damage by power-post beetles from the 7 treatments ($p< 0.01$).

TABLE III
THE EFFECT OF NON-CHEMICAL TREATMENT OF PRESERVATIVES FOR FUNGI DAMAGE (1 AND 2 WEEK PERIOD) IN LABORATORY

Piece of Bamboo	Water and heating		Lemon grass		Turmeric		Celery	
Week	1	2	1	2	1	2	1	2
1	3	3	3	3	3	3	2	3
2	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3
4	3	3	3	3	3	3	1	2
5	3	3	3	3	3	3	1	2
Average	3.00		3.00		3.00		2.30	

Piece of Bamboo	Wood vinegar		Tobacco		Neem leaf	
Week	1	2	1	2	1	2
1	1	1	1	1	3	2
2	1	1	1	1	3	2
3	1	2	2	2	3	2
4	1	2	3	2	3	2
5	1	2	3	2	3	2
Average	1.30		1.80		2.50	

Table III illustrates the effects of non-chemical treatment of preservatives for fungi damage (1 and 2 week periods) in laboratory tests. It was found that a wood vinegar solution was the best protection against power-post beetle damage (mean =

1.30). The second was a tobacco solution (mean =1.80) and the third was a celery solution (mean = 2.30). When comparing the wood vinegar solution against the method of water soaking and heating, it was found that immerging bamboo in a wood vinegar solution could reduce fungi damage by 56.67%. One-way ANOVA showed a significant difference between fungi damage from the 7 treatments and that the difference was highly significant (p< 0.01).

TABLE IV
THE EFFECT OF NON-CHEMICAL TREATMENT OF PRESERVATIVES FOR FUNGI DAMAGE (1 AND 3 MONTH PERIOD) IN FIELD STUDY

Piece of Bamboo	Water and heating		Lemon grass		Turmeric		Celery	
Month	1	2	1	2	1	2	1	2
1	3	3	2	3	2	2	2	3
2	3	3	2	2	2	2	2	3
3	3	3	2	3	3	2	3	3
4	3	3	3	3	3	3	3	3
5	3	3	3	3	3	3	3	3
Average	3.00		2.60		2.50		2.80	

Piece of Bamboo	Wood vinegar		Tobacco		Neem leaf	
Month	1	2	1	2	1	2
1	1	1	2	2	2	2
2	1	1	2	2	2	2
3	1	2	3	2	2	2
4	1	2	3	2	3	2
5	1	2	3	2	3	2
Average	1.30		2.30		2.20	

Table IV illustrates the effects of non-chemical treatment of preservatives upon fungi damage (1 and 3 month periods) in the field study. It was found that the wood vinegar solution was the best protection against fungi damage (mean = 1.30). The second was a neem leaf solution (mean = 2.20) and the third was a tobacco solution (mean = 2.30). When comparing the method of wood vinegar solution against the method of water soaking and heating, it was found that immerging bamboo in a wood vinegar solution could reduce fungi damage by 23.34%. One-way ANOVA showed a significant difference between fungi damage from the 7 treatments and that the difference was highly significant (p< 0.01).

In conclusion, the results in this part show that immerging bamboo in a wood vinegar solution displays the best performance amongst other natural preservatives for protecting against power-post beetle and fungi damage**.** Thus, the method of immerging bamboo in a wood vinegar solution would be most appropriate method for using bamboo as a shading device in this study.

III. THE SECOND EXPERIMENT INVOLVED DESIGNING A BAMBOO SHADING DEVICE

A. The Objectives of This Study

The aims of this experiment were to develop a characteristic and detailed design of a bamboo shading device. The prototype of the final bamboo shading device was proposed after being developed from lessons learned from all tested bamboo shading devices.

B. Research Methodology

There were four bamboo shading devices constructed and tested in this part. These bamboo shading devices were constructed in Sainham Village, Tumbol Pohnham, Ampur Chantrakarm, in the Thai province of Prachinburi. The design process applicable to these shading devices concerned with four primary issues: 1) the main structure (columns and beams), 2) the louver curtain, 3) the details of each joint between construction members, and 4) the installation details of jointing between the shading device and the building. Choice of sub-sequential options, completed by solving the problems and drawbacks of all previous options until the final option (option 4) was concluded. A comparison was made between the four options in terms of the number of workers, time consumed for construction, time consumed for assembly, and the outlook, as shown in Table V.

C. Results

The first option was designed to obtain an overall bamboo shading device by combining each panel of bamboo slat. All of the members of this first option were made using 3-year old *Pai Tong* bamboo. Each 60cm x 60cm x1cm thick constructed 10m panel contained several 5cm wide and 3mm thick bamboo slats. All of the slats were attached to an outer square frame using tenons, and the slats were inclined 30^{o} from the horizontal. The outer square frames of each panel were made of 1cm diameter clogged bamboo poles, and the end of each pole of the outer frame was cut at 45^{o} and connected using screws. All of the slatted panels were then connected using aluminium hinges. The first option for a bamboo shading device was installed onto the building using spring steel to brace 1 position of the right panel and 1 position of the left panel, and 2 positions of upper panel. After being installed for 28 days, it was found that there was deformation of the overall shape of the shading device. Notably, there were some tears in the areas around the aluminium hinges of the pole outer frames.

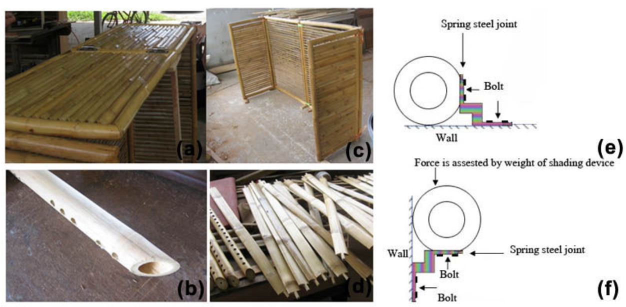

Fig. 1 (a) and (c) The first option of bamboo shading device contained panels of slats connected together by using aluminium hinges (b) 1cm diameter clogged bamboo poles with 45^{o} cut ends (d) 5cm wide and 3mm thick bamboo slats (e) The spring steel attached to right and left panels (f) Spring steels which braces the upper panels

The second option was developed from the first option, in having an additional main structure (columns and beams) as seen in Fig. 2 (a). The main column was made using 3-year old *Pai Tong* bamboo of lengths up to 1m and a diameter of 7cm. The main and sub-beams were also made using *Pai Tong* bamboo of lengths of up to 1.60m (the long side of the shading device) and 0.60m (the short side of shading device) and a diameter of 5cm. A 1m high and 1.60m wide panel containing bamboo slats was attached in front of the main structure as seen in Fig. 2 (b). There are eccentric connections between columns and beams using tightening two screws for each joint. This second option of bamboo shading device was attached to the building using 75mm x75mm x 6mm equal angles to brace 2 positions above the main beam. The other two equal angles were positioned at the left and right sides of the columns. After being installed for 28 days it was found that no deformation or tears to any member of this bamboo shading device option had occurred. However, this option required quite a large amount of bamboo and it was heavy.

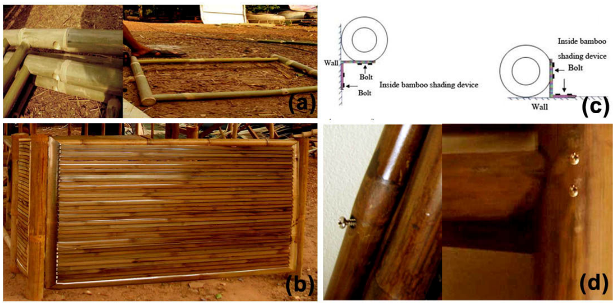

Fig. 2 (a) The second option of bamboo shading device consisted of main structure (columns and beams) (b) Four panels containing bamboo slats were attached in front of the main structure (c) Equal angles used to attach the shading device to the building (d) Connections use two screws for each point

The third option was developed from the second option. Bamboo slats were attached to two 3cm diameter sub-columns. There is only one main structure of column and beam, and there is no outer square frame for slatted panels for this option. All of the slats were inclined 30^o to the horizontal, and there were two sizes of slatted panel; one being 0.80m x1.00m and the other is 0.50m x 1.00m. Such columns penetrated the four main beams and were hammered together using nails. This option of bamboo shading device was installed onto the building using 75mm x 75mm x 6mm equal angles, similar to the method and positions used in option 2. It was also found that no deformation or tears to any member of this bamboo shading device option occurred after being installed onto the building for a 28 day period.

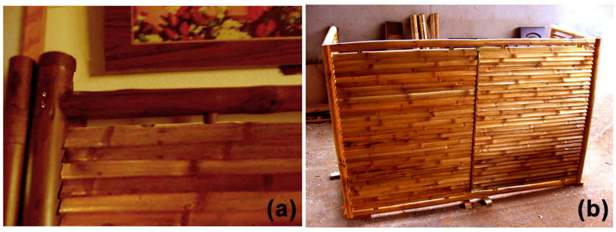

Fig. 3 (a) The third option of bamboo shading device contained bamboo slats attached to two 3cm diameter sub-columns (b) The main structure of columns and beams with slats

The fourth, and last option, was developed from the third option in order to improve privacy, and its beauty and ease of assembly. In this final option, for the upper part of the panel, the slats were inclined 30^o to the horizontal. For the lower part, the slats were inclined 60^o to the horizontal for privacy reasons. There are two couplets of sub-column for each panel. The sub-columns penetrated the four main beams and were connected to the beams using bolts. A couple of 1mm diameter sub-columns and smaller braced underside slats would help to receive each slat weight. They would also help to increase wind resistance. Each bamboo slat was attached to the couplets of sub-columns on each side of the panel. There were two sizes of slat panel in this final option, wherein one was 0.80m x 1.00m and the other 0.50m x 1.00m. This option of bamboo shading device was installed onto the building using 75mm x 75mm x 6mm equal angles similar to option 3. No deformation or tears to any member of this bamboo shading device after 28 days of installation were observed. In addition, it took only two workers seven days to construct this, taking only 15 minutes of assembly time.

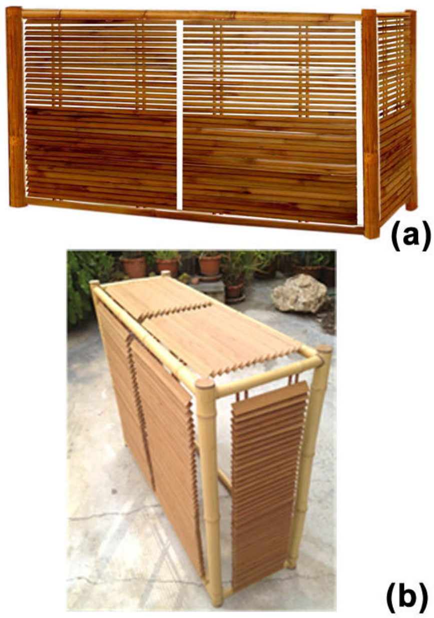

Fig. 4 (a) The final option of bamboo shading device contained 30^o inclined slats for the upper part and 60^o inclined slats for the lower part (b) Overall members of the final option

TABLE V
BENEFITS AND DRAWBACKS FOR FOUR OPTIONS OF BAMBOO SHADING DEVICE

Option 1	Option 2
Benefits	Benefits
•30 minutes for assembly •Modular in size •Ability to combine for larger window installation •Only 2 workers for production process •Only 5 days for production process	•30 minutes for assembly •Only 2 workers for production process •Only 2 workers for production process •Only 5 days for production •Strong and no deformation after installing onto building
Drawbacks	Drawbacks
•Weak and having deformation after installing onto building •Large amount of aluminium. •Not beautiful	•Crooked bamboo slats along panel width •Less amount of bamboo than option 1 •More beautiful than option 1
Option 3	**Option 4**
Benefits	Benefits
•25 minutes for assembly •Only 2 workers for production process •Only 7 days for production process •Strong and no deformation after installing onto building •Straight bamboo slats along panel width due to splitting into two panels •Less amount of bamboo used for production than option 2	•Only 15 minutes for assembly •Only 2 workers for production process •Only 7 days for production process •Strong and no deformation after installing on building •Straight bamboo slats along panel width due to splitting into two panels •Less amount of bamboo used for production than option 3 •More beautiful and privacy
Drawbacks	Drawbacks
•Required more privacy on the lower part, beautiful elements and ease of assembly	-

IV. CONCLUSION AND DISCUSSION

The main aim of this research was to investigate a prototype bamboo shading device. Two experiments were carried out for this purpose. The results in the first experiment showed that among seven treatments tested immersing bamboo in wood a vinegar solution showed the best performance for protecting against damage by powder-post beetles and fungi concerning bamboo shading devices. The second experiment was carried out by constructing four bamboo shading devices and installing them on buildings. The final prototype of shading device was developed from the lessons learned from the test results. The final prototype required only 2 workers and 7 days for its production process. It also only required 15 minutes of time consumed for assembly. It can thus create a more private view and is light weight. From the results of this study, it is clear that the future looks bright for the use of bamboo as a shading device, in terms of industrial production.

From this perspective, more action should be made to promote training programs for the industrial production of bamboo shading devices in potential rural areas of Thailand. The industrial production of bamboo shading devices would increase community based incomes in areas with a wealth of bamboo growth. It can also substantially contribute to promoting ecotourism in such areas. This situation could be vastly beneficial to reducing poverty throughout Thailand. This can be seen in Thanh Hoa province, where industrial bamboo creates a large amount of income to the province. Whilst, 10 years ago, Thanh Hoa used to be one of the poorest districts of Vietnam, nowadays it has become a famous ecotourism province of Vietnam [20], [21].

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